The Electric Power Industry and the Defense Program

By John D. Wilson, Chief of Business Analysis Section, Division of Business Review

IN the late summer and early autumn of 1917 the war effort of the United States began to be hampered by a shortage of electrical power in many of its chief industrial centers.[1] The shortage appeared first at Buffalo and the Niagara Falls region; next in the Pittsburgh, industrial Ohio sector; and spread eventually to New England, the Pacific coast, and certain areas of the South. By the spring of 1918 it had reached such serious proportions that a special section of the War Industries Board set out to deal with the problem. In the course of the following months this section installed a priority program in the critical areas, helped steam plants obtain necessary coal during times of stringency, established schedules for the repair of machinery—especially generators—which had broken down, and formulated plans for construction of new generating capacity and transmission lines. The organization of the program, however, required so much time that no large general increase in power supply had been realized before the armistice was signed and the program abandoned.

The power section of the War Industries Board had been only an advisory and planning group with no power to initiate a comprehensive program designed to alleviate the shortage. Though an act giving the section broad powers had passed the House, it did not become law before the Armistice intervened. Action taken in regard to new construction was performed by the Emergency Fleet Corporation, the Ordnance Department of the Army, or the Navy Department. Each agency either assisted in installing or directly installed additional capacity in sections where its program exercised such heavy demands that a shortage appeared. Thus, the Emergency Fleet Corporation installed 55,550 kilowatts at plants and shipyards; the Army helped install 100,000 kilowatts of generating apparatus and a number of miles of transmission line; and the Navy assisted in the provision of interconnecting transmission lines.

The experience of the last war has not been forgotten by either the industry or the public. As the defense program is certain to expand the demand for power very substantially, questions were immediately raised about the ability of the industry to handle the prospective increase. An investigation has been inaugurated by the Federal Power Commission with the cooperation of the industry, and certain results, on the basis of the defense problem as it exists today, have been announced. The most important of these are presented below. However, an appreciation and understanding of the nature of the problem requires some knowledge of recent developments in the demand for electricity on the part of principal consumer groups, as well as an awareness of the development of supply over the past decade. These questions are first examined here.

Large Increase in Demand and Facilities Since War.

The 20-year period following the war was one of vast change and development of electric power facilities and use. Output in 1939 was five times the 1917 volume, while generating facilities had increased fourfold. The larger proportion of the development occurred in the twenties. During this decade the industry not only had its most rapid rate of expansion, but it also underwent a profound alteration in organization from local operating companies to large interconnected systems.

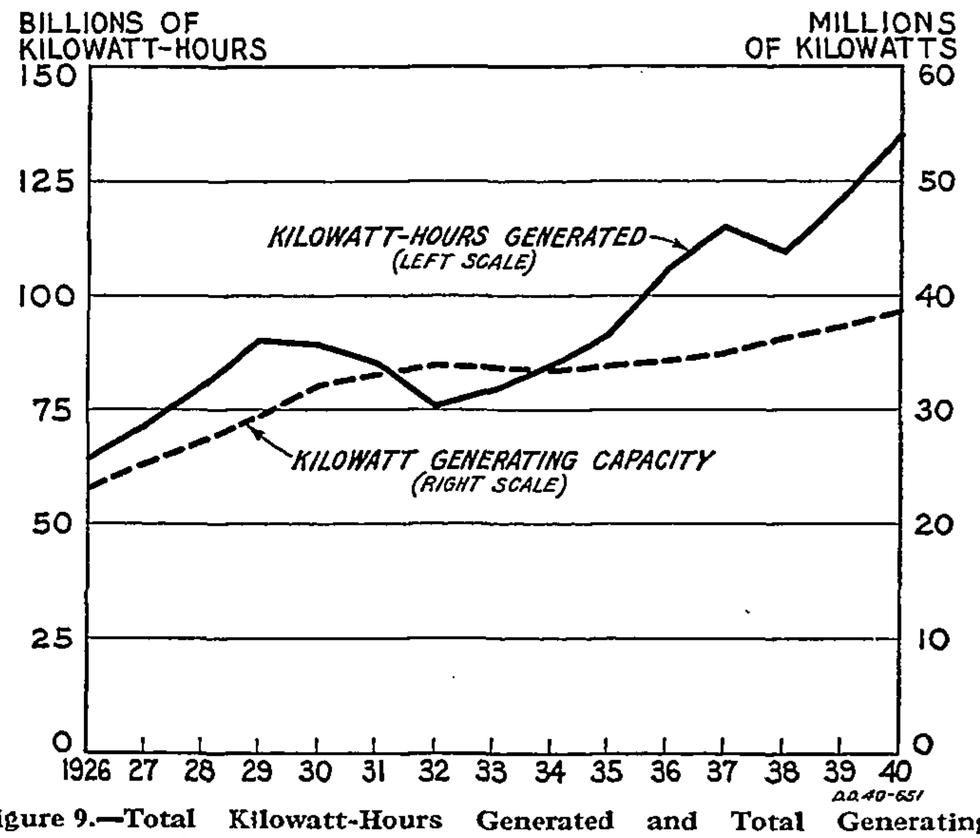

Figure 9.—Total Kilowatt-Hours Generated and Total Generating Capacity, 1926–40 (Edison Electric Institute).

NOTE.—Data represent kilowatt-hours generated during the year and the generating capacity on December 31.

After a period of reduced demand in the early thirties, as shown in figure 9, expansion was again continued, though at a slower pace. As is to be expected, this year has been no exception to previous experience. For the past several months electric-power output has been at an all time record as a result of increased demand on the part of every major consuming group. Daily power production in November averaged 434,000,000 kilowatt hours, 9 percent more than in the same period last year.

[1] Discussion of the War experience is to be found in "*The Power Situation During the War*," War Department Document 1039, Office of the Chief of Engineers (out of print).

Production in the first 9 months surpassed the 1939 volume by 13 percent, the smaller percentage gain in the last several months being the result of the rapid rise in output after September 1939, and not to a downward trend this year. As will be shown in more detail later, the evidence now available points to an even larger increase in demand next year. It must not be forgotten that today electric power is much more a necessity in everyday life than it was in 1917 and 1918. This is true both in industrial production and in the life of the average household. Only in transport and a few other industries would rationing effect such an inconvenience.

Capacity in the Industry.

The concept of capacity in the industry is a peculiarly difficult one. For example, it is often stated in terms of rated kilowatts of installed generating plant, the implication being that this amount of power should be available when needed. Yet break-downs occur and repairs must be made; so extensive reserves are required. Moreover, many plants cannot be operated all the year. This is especially the case in hydroelectric plants, where varying water conditions determine the extent of plant utilization. In reality, only the operating companies, through long experience and detailed knowledge of individual units, are in a position to state the output they can assure at any particular time of the year.

Moreover, knowledge of assured capacity in the country as a whole may prove misleading. It is a fact that the sum of peak demands in all sections of the country during September was only about 69 percent of installed generating capacity. But even assuming that the total capacity is assured capacity, one cannot deduce from this that no shortages would appear in the country as a whole if the over-all peak demand increased by 31 percent or less. Power must be available in the particular region of demand. A surplus in Oregon is not available for increased demand in Pittsburgh. However, the radius of the region to which power from a particular area can be made available by transmission has grown steadily over the past two decades. In this respect the situation today is much different from that in 1917–18 when the state of technique and inadequate facilities seriously limited interchange of power between areas. Today it is not impossible to transmit power 300 miles, and a surplus in one area can be and is used to satisfy deficiencies in other areas not too far distant.

Because demand is not of continuous intensity but rises to peaks at certain times of the day and year, it is possible for output to increase considerably at off-peak times without making necessary any addition to generating capacity. For example the addition of an electric water heater to a residential load more than doubles kilowatt-hour consumption of the residence, but the heater may be fixed so as to operate only at off-peak times. Some idea of the extent to which such off-peak capacity is available is given by the fact that in September consumption of electricity was only about 40 percent of the total which the plants of the country were capable of producing.

With the above general remarks as an introduction, what can be said about the present capacity of the industry? First examine the over-all picture. Figure 10 shows the movement of installed generating capacity over the past 15 years. It can be seen that installations from 1930 to 1939 were small as compared to the previous decade. In the 9 years prior to 1940, 5,327,000 kilowatts were added, little more than the new installations made in the 2 years 1929 and 1930.[2] Meanwhile, during the thirties demand had increased 35 percent. Even though the industry had built considerably ahead of demand in the latter twenties, a more rapid expansion was to be expected after 1939. This is now being realized, for additions to installed capacity in the past year were the largest since 1930. Moreover, they will be surpassed in 1941 and possibly in 1942. Final information about last year's increase in generating capacity is not available. However, reports from the industry indicate that plant and equipment representing more than 1,350,000 kilowatts was introduced by private and municipal utilities, bringing the total installed capacity to 38,726,000 kilowatts. The industry also reports that facilities under construction or on order will add 2,150,000 kilowatts in 1941, and that this will be supplemented by large additions in governmental power districts, particularly in the Pacific Northwest. A somewhat smaller increase has been scheduled to date for 1942. Thus, the new capacity installed in these 3 years will probably exceed the total introduced from 1930 to 1939.

In the latter part of the twenties the electric-light and power industry yearly spent between $700 and $800 million on new plant and equipment, the highest amount being realized with the expenditure in 1930 of $919 million. Three years later annual investment had dropped to $129 million. Since that time, however, it has steadily increased. Last year almost $600 million was expended, and the average investment of the next 2 years will probably match that of the late twenties.

Growth of Residential Demand Important Development.

Having examined the proposed increase in capacity, turn now to the nature of demand in the industry. Demand for electricity is usually classified according to the type of consumer. Three groups are outstanding: Industry, which consumes 50 percent of the output; commercial firms, which require about 19 percent of total production for lighting and small amounts of power; and finally, demand by residential households, consuming another 19 percent.[3]

Figure 10 pictures the course of requirements in each

[2] Generating capacity used here represents that of privately owned central stations, plants owned by the T. V. A., the rural cooperatives, and municipal plants. Data may be found in Edison Electric Institute Statistical Bulletin No. 7, 1939, p. 7.

of these markets over the past 15 years. One very outstanding development during the last decade was the steady expansion of the residential market. The average annual use of electricity by each household

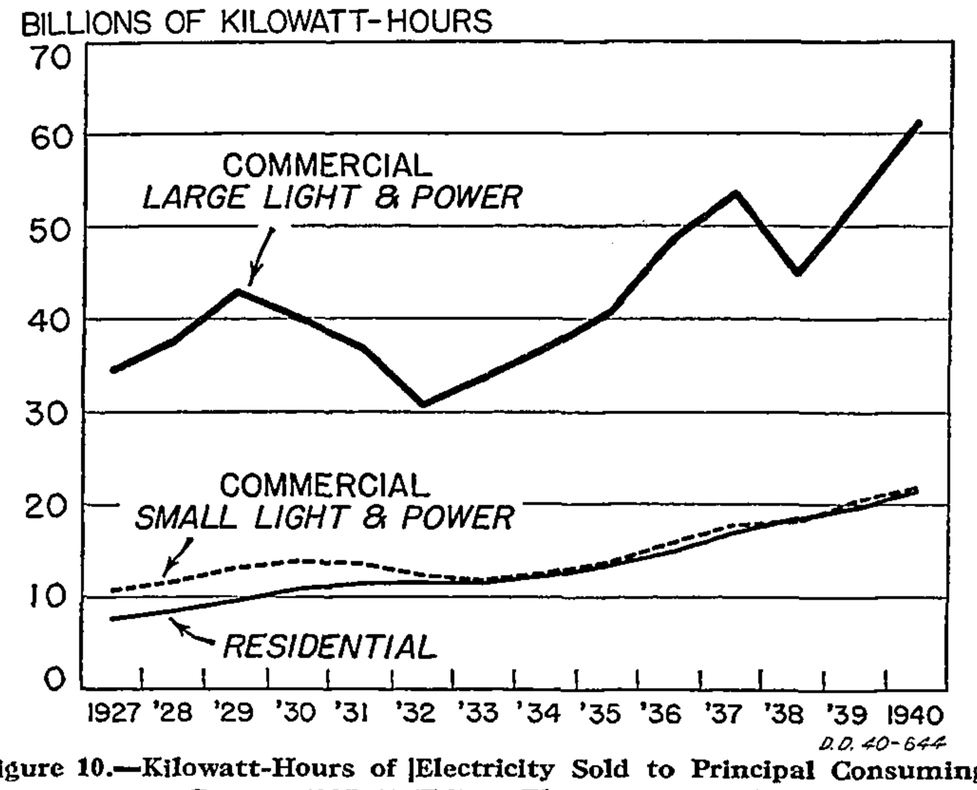

Figure 10.—Kilowatt-Hours of Electricity Sold to Principal Consuming Groups, 1927–40 (Edison Electric Institute).

NOTE.—Data for 1940 are estimated.

increased 80 percent during the period, while the total kilowatt-hours sold to residential consumers more than doubled. In the past year the trend was continued, the 12 percent gain being a typical average for the period since 1934. Construction of additional residences created some of the new demand but of more importance was the steady expansion in the ownership and use of electrical appliances. Before 1924 relatively few households used electricity for anything but lighting and small appliances. Since then many new appliances have been introduced and those rarely used have become common. Whereas in 1924 the bulk of demand stemmed from lighting and a few small appliances, by 1939 refrigerators were responsible for 22 percent of the total, ranges for 10 percent, radios for 9 percent, and water heaters for 8 percent.

Knowledge of the factors which have influenced the growth in appliances is necessary for any appraisal of future demand. Four have been of paramount importance: The technological changes which have reduced appliance prices and improved their quality; reductions in electrical rates; a rise in the level of income; and the promotional efforts of appliance dealers and the utility companies. There is no question but that the last factor has been of great importance, though it cannot be measured quantitatively. Promotional technique has been thorough and intensive, and it has yielded results. The other factors none the less play a more important role.

Consider first the effect of reductions in the price of electricity. In recent years, about one-third of the rate schedules have been lowered annually. From 1929 to 1940 such changes reduced the average price for 100 kilowatt-hours from 5.1 cents to 3.9 cents a kilowatt-hour, while the average price for 250 kilowatt-hours declined from 4.3 cents to 2.8 cents. However, these rate reductions themselves have been partly induced by the increase in consumption. The cost of producing a kilowatt-hour of electricity for residential purposes has usually diminished much more rapidly with increasing output than the companies had anticipated when the rate schedules were set up. Much of the new demand has not required a proportionate increase in generating investment and the incremental operating cost has been small. Moreover, by far the largest element of the total cost at present consumption levels—more than two or three times the generating cost—is incurred in distributing the electricity from the substation to the home, and increasing consumption entails little addition to this type of cost.[4] Thus the addition of a large refrigeration load due to promotional efforts of appliance dealers would in itself have made many reductions in rate schedules possible.

The actual amount paid by residential consumers for electricity has declined more than the reduction in rates themselves, falling from 6.3 cents a kilowatt-hour in 1930 to 4.03 cents in 1939. In the past year the average cost was 3.88 cents. That part of the cost reduction which has not been the result of lower rates has followed automatically from increased consumption because most utilities have adopted graduated rate schedules.

In many instances rate reductions do encourage increased consumption directly, or at least the increased consumption would not be forthcoming without them. This is especially true in those areas where electricity is not furnishing a new or a substantially better service, but must compete with substitutes on a price basis. The most important cases of this type are the electric range and water heater, the two appliances consuming by far the largest amounts of electricity. If the rate for the additional quantity of electricity needed to operate a range is more than 2 cents a kilowatt-hour, or that needed to operate a water heater is more than 0.8

[3] Remaining demand is distributed as follows: Street and interurban electric railways, 4 percent; rural demand for light and power, 3 percent; municipal street lighting, 1.5 percent; electrical division of street railways, 1.5 percent; municipal and miscellaneous, 2 percent.

[4] For cost data see: Power Authority of New York, *Report on Cost of Distribution of Electricity*, 1934, and *Eighth Annual Report*, for year ended December 31, 1938, Albany, J. B. Lyon and Co., Printers; Federal Power Commission, *Cost of Distribution of Electricity*, 1936, Washington, United States Government Printing Office; and *Are Electric Ranges Profitable*, H. A. Snow, Electrical World, February 11, 1939, p. 47, and February 25, 1939, p. 46.

The Power Authority of New York found the following average unit distribution costs for different average annual domestic consumption in kilowatt-hours per year in the New York State region:

Average consumption in kilowatt-hours:	Average distribution cost per kilowatt-hour
600	2.5
1200	1.415
1800	1.0
3000	.632
6000	.366

Thus, distribution cost is large relative to generating cost only when average consumption is small.

cent a kilowatt-hour, the electrical appliances often find it difficult to compete with gas. But at these rates they usually attract new customers.[5] Though both the range and water-heater loads are a considerable total, only a relatively small number of customers own these appliances—about 10 percent in the case of ranges and less than 4 percent in the case of water heaters.

Perhaps an even more important factor inducing load growth in the past than rate reductions has been the technical changes which have improved the quality, lengthened the life, and helped lower the price of many

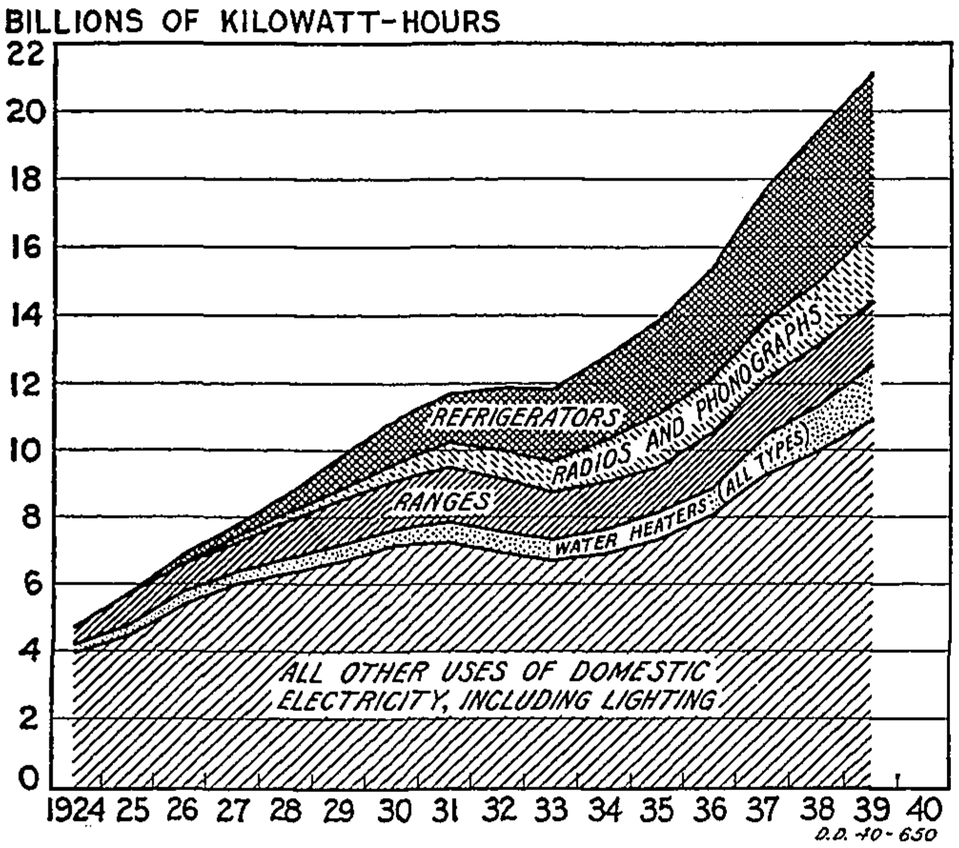

Figure 11.—Energy Used by Various Domestic Electric Appliances, 1924–39 (Edison Electric Institute).

appliances. These effects are well illustrated in the case of the refrigerator. Between 1921 and 1937 the average cost of the refrigerator was reduced from $550 to $173, and technical improvements increased its life expectancy from 7 to 15 years. These changes reduced the annual cost to the consumer for depreciation and interest so as to realize a saving of $90 a year in the cost of refrigeration. In the same period rate reductions yielded an annual saving of $11.46 in the cost of refrigeration. A similar situation prevails with the majority of other appliances, most of which consume only a small amount of electricity. The range and water heater, however, are significant exceptions. For prices have been lowered and life expectancy increased in the case of each of these, but the resultant saving to consumers has been less than that given by rate reductions.

Insofar as year-to-year changes in the rate of increase of demand are concerned, lower appliance prices play a smaller part than shifts in the level of income. Thus, in the past year refrigerator prices declined 11 percent and range prices 6 percent. Sales of refrigerators were 2,567,000, 40 percent over the previous year, while range sales increased 34 percent.[6] The lower prices did furnish some stimulant to sales, but a more important factor was the higher level of income during the year.

Sales of all appliances reveal the same general movement from year to year, rising above the average associated with the trend in periods of high income and falling below this average in periods of low income. This wavelike movement, of course, may be superimposed on a downward trend, the expansion demand in the market giving way to a growing replacement demand. The influence of income on demand can also be demonstrated in another way. This is done in figure 12

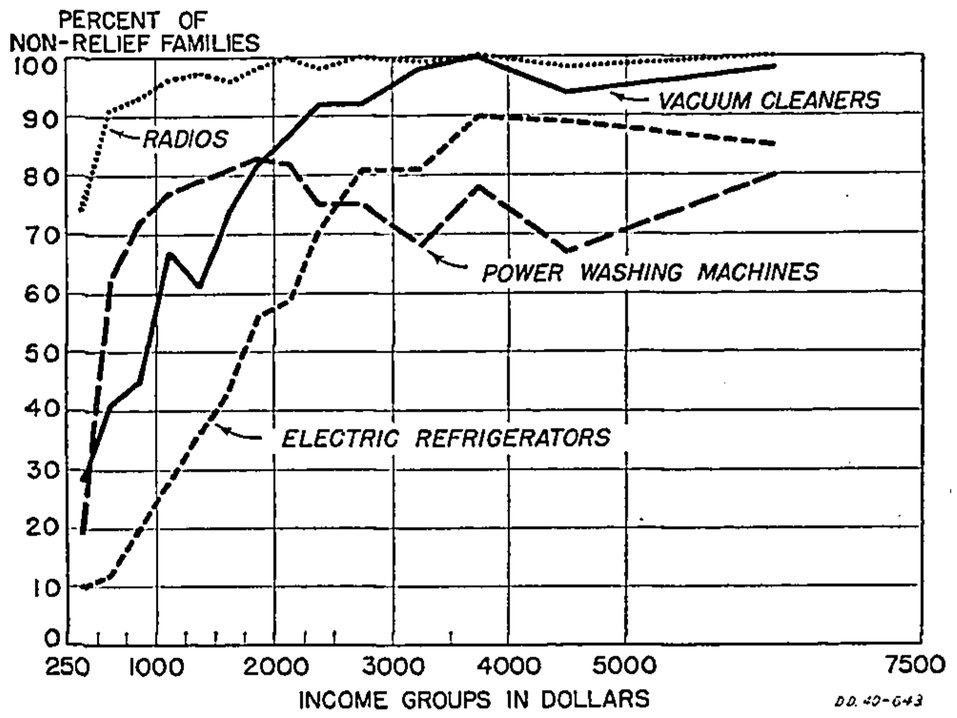

Figure 12.—Household Equipment Ownership by Income Groups, 1935–36 (U. S. Department of Labor, Bureau of Labor Statistics: Study of Consumer Purchases, Urban Series).

NOTE.—Data are for middle-sized cities in the east central part of the United States.

which shows the percentage of families in various income classes who owned electric refrigerators, power washing machines, vacuum cleaners, and radios in the year 1935–36.[7] As might be expected, the higher the income class, the larger the proportion owning various appliances. While less than 30 percent of the families with incomes of $1,000 a year owned electric refrigerators, more than 80 percent with incomes of $3,000 a year had them. Only in families with an annual income less than $750 was the possession of a washing machine unusual.[8] Sixty percent of families in the $1,000 income class owned vacuum cleaners as contrasted with the 100 percent in the $3,750 group. Radios were more evenly distributed, 85 percent of the families with incomes of only $500 a year owning this equipment.

Each of the above factors influencing the growth of residential demand is expected to act with increased intensity this next year. Under the stimulus of a record level of income, appliance sales should surpass those of 1940. This in turn should help to extend the

[5] Obviously, rates necessary for successful competition vary from area to area as gas rates and other variables differ. The above rates are typical, however, for the competitive situation which exists in many communities.

[6] Water-heater sales increased 15 percent; vacuum cleaners, 10 percent and washers, 10 percent.

[7] Only nonrelief native-born families are included. The area to which these figures refer is limited to middle-sized cities of the East Central part of the United States. Similar results as far as the general movement is concerned are given for cities of all sizes in all sections of the country. See *Price Behavior and Business Policy*, Monograph No. I, T. N. E. C., Investigation of Concentration of Economic Power, section prepared by Saul Nelson and W. C. Keim, pp. 122-129.

[8] The apparent exception in the case of those owning electric washers is misleading. The decline in the percentage of ownership by those having incomes above $2,000 is the result of the large number of such families who send washing to laundries and hence use power machinery indirectly.

downward movement in rates and appliance prices, both of which will reinforce the strong demand for electric power.

Changes in Industrial Consumption.

In the past year industrial consumers of electricity increased their purchases more than any other group. The higher level of industrial production during the first 9 months of 1940 required 18 percent more electricity than was used in the same period last year.

Though industrial demand for central-station electricity is directly correlated with changes in the volume of industrial production,[9] three factors have altered the relationship over longer periods of time. These are, first, a secular trend on the part of all industries toward the use of more electricity in the production process; second, a change in the pattern of demand toward commodities which use more electricity than those which they displace; and third, a continuing substitution of central station power for that generated by individual mining and manufacturing firms themselves.

Table 1.—Indexes of Physical Output and Purchased Electric Energy, Manufacturing Industries, 1937

[1929=100]

Industrial group	Volume of physical output	Purchased electric energy
Total, all industries	103	128.3
Food, excluding beverages and liquors	104	112.3
Textiles	106	131.5
Forest products	76	119.0
Paper	122	109.5
Printing and publishing	102	115.7
Chemicals	124	137.7
Petroleum and coal products	114	185.5
Rubber products	91	116.2
Leather	108	118.1
Stone, clay, and glass products	100	107.9
Iron and steel	89	151.0
Nonferrous metals	89	102.7
Machinery	(1)	130.6
Transportation equipment	91	116.8
Miscellaneous	(1)	191.4

[1] Data for machinery and miscellaneous are insufficient to permit the construction of group indexes. These groups, however, are covered by the total index.

Sources: National Bureau of Economic Research and Bureau of the Census.

An idea of the extent to which industry is using more electricity is given in table 1 which presents indexes of physical production and purchased electric energy for the various Census groups of manufacturing industries in 1937, using 1929 as the base year. This table shows that the volume of physical production in 1937 was 3 percent greater than in 1929, but that purchases of electric energy increased 28 percent. Only in the paper industry did the gain in purchases of electric energy fail to exceed the advance in production. The largest increase in purchase of energy was made by the petroleum and coal products and iron and steel groups, both of which contained industries experiencing considerable technological change between 1929 and 1937. These changes resulted in the introduction of special electrical processes as well as an increased use of power-driven machinery.

How much of the larger consumption of electricity represented technological change and how much was the result of reduced generation by industry itself and, hence, increased purchases from central power stations, cannot be determined with the existing data. There is reason to believe, however, that technological change was by far the more important factor. Regardless of the importance of each, it is clear that estimates of future industrial demand from power stations must make allowance for this secular growth.

The defense program is significantly changing the pattern of demand facing the industrial community over the next few years. Many industries will achieve an importance they have never experienced before or have not witnessed since the last war. These are well known—including, among others, shipbuilding, airplane manufacturing, ordnance and ammunition, machine tools, chemicals, nonferrous metals and steel. All of these industries use more electricity per laborer than the average, and some of them stand at the very top of the list. The electrometallurgical and electrochemical industries of course top most other industrial consumers of electricity, and their importance is being considerably expanded.

Since the volume of industrial production in 1931 is expected to register a large gain, industrial demand for power will show an increase of similar magnitude. This increase will be further supplemented by construction of new plants in many industries introducing the latest technological changes, most of which require more electricity than older methods of production. For example, capacity of the aluminum industry, now almost exclusively an electrometallurgical industry, is to be increased 77 percent during the next 2 years, and substantial additions to electric-furnace capacity in the steel industry are scheduled. Finally, the wide shift in the pattern of demand created by the defense program will act as another factor tending to increase demand more than that ordinarily induced by an expansion of industrial production.

Further Expansion in Commercial Demand.

Much less is known about the relative importance of various factors influencing the growth of demand on the part of commercial consumers. Here, too, there has been a steady increase in consumption, though the rate of increase has declined in recent years. Promotional activity, lower rates, technological change,[10] and a secular growth in the relative importance of services in the economic life of the community have produced an average annual increase in consumption of 9 percent since

[9] Besides cyclical changes, the volume of industrial production still continues a secular advance associated with the growth of population and the increase in industrialization of the economy.

[10] One technological development of especial importance has been the growth of air-conditioning in such commercial enterprises as theaters, stores, hotels, and other establishments. Not only has air-conditioning increased demand, but it also has altered the shape of the daily and annual load curve. Winter requirements formerly were greater than those in summer. Air-conditioning demand has reversed this situation in some areas, while in others summer requirements are now almost the equal of those in winter.

1933. Last year the increase was 8 percent. Here, too, the rate of growth is profoundly affected by changes in the level of income. In the early thirties commercial consumption actually decreased with the decline in income, and the rate of increase was curtailed by the fall of income in 1938. Thus, the higher income anticipated next year is expected to supplement the secular factors mentioned above in creating an advance in consumption well above that of 1940.

Power Commission Indicates Capacity Additions Inadequate in Certain Areas.

It is apparent that a large increase in the consumption of electric power on the part of all major groups of consumers may be expected next year. Similarly, as was pointed out above, a substantial expansion in generating capacity is scheduled. But early in this discussion it was shown that a view of the over-all situation alone was inadequate. What about the changed demand in specific areas relative to the capacity increase? Any answer to this question requires an involved examination of large masses of data. Yet since 18 months to 3 years are necessary to construct additional plant, an answer must be sought.

The industry is currently cooperating with the Federal Power Commission in its effort to predetermine areas where additional capacity will be urgently needed. The country has been divided into 48 areas and the power situation in each of these has been surveyed. Estimates were supplied by the utility industry of the probable maximum requirements in each area before September 1941 as well as the assured capacity scheduled for the end of 1940, 1941, and 1942. Though the situation changes frequently, The Federal Power Commission, has used these data, together with information on the distribution of defense contracts, and knowledge of the course of demand by different consuming groups in each area, to determine the adequacy of the proposed facilities. The Commission concluded that capacity is sufficient for handling loads expected this year. However, it also revealed the need for still further expansion in some areas if deficiencies are to be avoided when the present defense program attains its peak in 1942. The following areas have been listed as those where the greatest need is likely to develop:

1. Upper New York State.
2. The Philadelphia region—Eastern Pennsylvania and New Jersey.
3. The Pittsburgh region—Western Pennsylvania.
4. Chicago, northern Illinois, and northern Indiana.
5. St. Paul and eastern Minnesota.
6. Southeastern States, including Tennessee Valley area, North and South Carolina, Alabama, and Georgia.
7. Arkansas, northern Louisiana and western Mississippi.
8. Idaho and Utah.
9. San Francisco, northern California and southern Oregon.

The table below presents the data submitted by the industry for these 9 areas. Estimated maximum requirements for 1941 in most cases represent an extrapolation of the trend of growth over recent years. Since defense needs are expanding demand at a greater rate than is shown by the trend, maximum requirements in most areas have been underestimated. Moreover, as the national defense program will not attain its peak before 1942, demand at this time should be substantially in excess of that for 1941.

Area	Peak load October 1940 (thous. of kws.)	Estimated maximum requirements between Oct. 1940 and Oct. 1941 (thous. of kws.)	Date when these requirements will be reached	Net assured capacity to serve annual peak load,[1] end of—		
				1940	1941	1942
No. 1	1,850	1,871	Dec. 1940	1,843	1,953	2,028
No. 2	2,390	2,550	Oct. 1941	2,690	2,912	3,102
No. 3	1,084	1,110	Dec. 1940	1,239	1,316	1,403
No. 4	1,641	1,800	Oct. 1941	1,706	1,860	2,000
No. 5	392	408	Dec. 1940	471	521	521
No. 6	1,847	2,056	Oct. 1941	1,739	1,949	2,297
No. 7	271	307	Sept. 1941	281	288	288
No. 8	224	249	Aug. 1941	246	246	246
No. 9	1,210	1,299	July 1941	1,276	1,320	1,395

[1] Net assured capacity is the installed generating capacity (assuming critical water conditions in the case of hydroelectric plants) with adjustments for the net effect of firms capacity interchanges within the district and minus the required reserves as reported by the systems.

On the basis of present construction schedules, deficiencies in 1942 for the above nine important areas are estimated by the Commission to aggregate more than 1,500,000 kilowatts. As it takes 18 months to 3 years for the provision of additional generating facilities, part of this possible deficiency will have to be relieved in some other fashion. Many of the critical areas are adjacent to or within transmission distance of other areas having surplus power, and since construction of high-voltage transmission lines requires only 6 months to 1 year, it is expected that these surpluses will be used extensively to relieve shortages.

In conclusion, the difference between the situation today and that in 1917 and 1918 needs to be emphasized. Today large additions to capacity are already under construction, whereas in 1917 and 1918 the industry seriously curtailed its expansion because of rising construction costs and interest rates. Moreover, at that time capacity for the production of electrical equipment was inadequate to handle Army, Navy, industrial, and central station requirements. Finally, the state of technique and the organization of the industry were such as to make impossible the construction and use of interconnecting transmission lines on a large scale. At the moment none of these factors appears to be a serious threat to current expansion, though it is possible that developments in the next year may make the situation less favorable than it now is insofar as costs and machinery capacity are concerned. Nevertheless, if shortages in particular areas are correctly anticipated, repetition of experience in 1917 and 1918 should be averted.